

ROCKET MEASUREMENTS OF COSMIC NOISE INTENSITIES BELOW 5 MC/S

by

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ABSTRACT

Cosmic radio noise intensities at four frequencies below 5 Mc/s were measured with a rocket probe launched from Wallops Island, Va., on 23 October 1964. The experimental payload which consisted of a short dipole antenna, four TRF receivers, a reference noise source and an antenna impedance probe reached an apogee altitude of 1070 km during the 20-minute flight. The measured cosmic background noise intensities were

$$(2.2 \pm 0.9) \times 10^{-20} \text{ w/m}^2/\text{cps/sr. at 1.91 Mc/s,}$$

$$(2.7 \pm 0.5) \times 10^{-20} \text{ w/m}^2/\text{cps/sr. at 2.85 Mc/s,}$$

$$(1.7 \pm 1.1) \times 10^{-20} \text{ w/m}^2/\text{cps/sr. at 3.60 Mc/s,}$$

$$(2.2 \pm 1.4) \times 10^{-20} \text{ w/m}^2/\text{cps/sr. at 4.70 Mc/s.}$$

These results, which are for a hemisphere centered near the North Galactic Pole, are not inconsistent with an interpretation of the turn-over in the noise spectrum below 5 Mc/s as being due to absorption by nearby galactic HII regions having an emission measure the order of $5 \text{ cm}^{-6} \text{ pc}$.

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INTRODUCTION

Since radio astronomical measurements are severely hampered by the ionosphere at frequencies below about 10 Mc/s, observations in this frequency range must be performed with high altitude rocket probes or satellites. There have been some ground-based observations under very special conditions (Ellis, 1964), but this approach is quite difficult at best. This concern is born out by the results of recent space-borne experiments which are not entirely consistent with the measurements of cosmic noise intensities below 5 Mc/s obtained from the ground. Rocket probe measurements of the average cosmic noise intensities at 1.225 and 2.0 Mc/s by Walsh et al (1963) agree with the suggestion by Ellis and co-workers that the radio spectrum falls off sharply in this range, although the rocket intensities are nearly twice the intensities derived from the ground observations. A high altitude rocket measurement by Eugenin et al (1963) at 2.2 Mc/s agrees more closely with the ground-based results, but the experimental uncertainty in the rocket data is too large to help resolve the discrepancy between the other rocket and ground observations. Alouette satellite measurements reported by Hartz (1964), on the other hand, suggest that the cosmic noise spectrum between 1.5 and 5 Mc/s is flatter than observed by either Ellis or Walsh et al.

In order that this situation might be resolved to provide a more consistent picture of the cosmic noise spectrum, a radio astronomy rocket probe was launched to an altitude of nearly 1100 km above Wallops Island, Virginia, on October 23, 1964. The payload was instrumented to measure average noise intensities at 1.91, 2.35, 3.60 and 4.70 Mc/s. A report of this experiment and a discussion of the implications of its results follow.

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EXPERIMENT INSTRUMENTATION

The radio astronomy instrumentation was comprised of a short (9.76m) dipole antenna which was connected through appropriate matching networks to four TRF receivers plus a comparison noise source and a probe to measure both resistive and reactive components of antenna impedance. A pair of orthogonal magnetometers and a solar aspect sensor provided supporting information regarding vehicle spin and aspect. A block diagram of the experiment is given in Figure 1.

The telescoping dipole was initially folded under the payload nose cone and was then erected to its full length after 130 seconds of flight at an altitude of about 225 km. An internal programmer alternately connected the antenna to the input of the receiving system and to the input terminals of the impedance probe. As shown in Figure 1, the receivers were operated in pairs so that when one pair of receivers was sampling the antenna (e.g., at 1.91 and 3.60 Mc/s) the other pair (2.85 and 4.70 Mc/s) was connected to the comparison noise source for calibration. The comparison noise source, in turn, was programmed to provide three levels of calibration - a zero level, a level near the middle of the receiver dynamic range, and a high level signal. The full program sequence is given in Figure 2. For the first 15 seconds of the duty cycle the receivers alternately sample the antenna and the noise source in 2.5-second intervals. For the final 5 seconds of the program cycle the antenna impedance probe is on, and the receivers are inoperative.

EXPERIMENTAL RESULTS

The experiment was launched on a four-stage Javelin rocket at 16^h00.6^m U.T. on October 23, 1964, and reached an apogee altitude of 1070 km after about 10.5 minutes of flight.

Good data were obtained from antenna deployment at about 225 km altitude until the payload re-entered the ionosphere at about 200 km altitude. The vehicle was above 1000 km for about 5 minutes, and only noise data obtained during this period were used for the cosmic noise intensity analysis. The Explorer XX topside-sounder satellite passed directly over Wallops Island about 20 minutes before launch, and the sounder data showed the local electron plasma frequency at 1030 km to be less than 850 kc/s.

The raw noise data in the form of receiver output voltages for each frequency are plotted in Figure 3. The vertical scales have been displaced for easier inspection, and hence the relative noise values from frequency-to-frequency have not been accurately preserved. Notice that at the lowest frequency (1.91 Mc/s) the receiver output begins at a relatively low level and then increases sharply to a peak at about 600 km altitude. After falling abruptly in about 30 seconds, the apparent noise level then shows a gradual rise to a plateau centered about flight apogee. As the vehicle descends the pattern is repeated in reverse - a gradual decrease, then a sharp noise enhancement, and finally a decline to a low level at altitudes below 400 km. Each data point in Figure 3 represents an average value for each 2.5-second sampling interval. The noise output was actually strongly spin-modulated below about 700 km, although no clear evidence for spin modulation could be detected when the payload was much above that altitude. The uncertainty in the telemetry system and in data reading is shown by the error flags. At 2.85 Mc/s the general variation of noise level with altitude was the same except that the noise enhancement peak occurred at a lower altitude. This trend is further verified by the 3.6 and 4.7 Mc/s data. The 3.6 Mc/s noise enhancement

was observed to begin immediately after antenna deployment before the corresponding events at 2.85 and 1.91 Mc/s and after the lower frequency events at the end of the flight. At 4.7 Mc/s, only the end of the enhancement event appears to have been observed during ascent, and there is no indication of an enhancement on the descending leg of the flight.

Examination of the impedance probe data showed the noise enhancements to be associated with resonance effects in the antenna impedance when $1-Y < X < 1$, $Y < 1$. Notice that the observed signal level was extremely steady at 3.6 and 4.7 Mc/s throughout the eleven-minute period when the vehicle was above 700 km.

Using the antenna impedance values measured at apogee, the receiver data obtained at altitudes above 1000 km have been converted into cosmic noise intensities at each frequency. They are

$$(2.2 \pm \begin{smallmatrix} 0.9 \\ 0.6 \end{smallmatrix}) \times 10^{-20} \text{ w/m}^2/\text{cps/sr. at 1.91 Mc/s,}$$

$$(2.7 \pm 0.5) \times 10^{-20} \text{ w/m}^2/\text{cps/sr. at 2.85 Mc/s,}$$

$$(1.7 \pm \begin{smallmatrix} 1.1 \\ 0.7 \end{smallmatrix}) \times 10^{-20} \text{ w/m}^2/\text{cps/sr. at 3.60 Mc/s,}$$

$$(2.2 \pm \begin{smallmatrix} 1.4 \\ 0.9 \end{smallmatrix}) \times 10^{-20} \text{ w/m}^2/\text{cps/sr. at 4.70 Mc/s.}$$

The uncertainty estimates include the possible errors in the radiometer system calibration, telemetry system and data reading, and instrumentation performance in flight. The intensity measurements at 1.91 and 2.85 Mc/s are the most reliable and have an uncertainty of ± 1.5 db and $\begin{smallmatrix} +0.8 \\ -0.9 \end{smallmatrix}$ db, respectively. Due to a nonlinearity in the receiver response curves at 3.60 and 4.70 Mc/s, however, these measurements must carry an uncertainty greater than ± 2 db.

The observed cosmic noise intensities are plotted in Figure 4 along with other measurements of the noise spectrum

in this frequency range. Since our measurements refer to the hemisphere centered at about $l_{II}=100^\circ$, $b_{II}=80^\circ$, we have plotted the curve from the Alouette satellite measurements by Hartz (1964) for the North Galactic halo region. Since Alouette is at an altitude of about 1000 km these measurements should be comparable, and there is agreement within the uncertainties of the two sets of measurements. The data obtained from the ground by Ellis (1964) are for the region of the South Galactic pole, but were obtained with a more directive antenna than the space-borne experiments. The measurements of Walsh et al (1963) are for a hemisphere centered on $l_{II}=144^\circ$, $b_{II}=-19^\circ$, whereas the observations by Huguenin et al (1962) represent an average over nearly the whole celestial sphere. Both the measurements from the ground and from the Michigan rocket suggest that the cosmic noise spectrum has begun to fall off sharply in the neighborhood of 2 Mc/s, and this has been widely interpreted to be due to free-free absorption in ionized galactic hydrogen having an emission measure $\langle N_e^2 L \rangle$, of about 4 to 6 pc cm⁻⁶. The new measurements at 1.91, 2.85, 3.60 and 4.70 Mc/s are consistent with that interpretation.

The rocket and satellite measurements have been re-plotted in Figure 5 for comparison with a straight line extrapolation of the spectrum observed at high frequencies as shown by the dashed line. The background intensity has been taken to vary as $f^{-0.6}$ in this extrapolation. If one then assumes that there is uniform absorption by HII, then the observed intensity will be

$$I \approx I_0 \exp \left(\frac{-0.17}{f^2} \int \frac{N_e^2}{T^{3/2}} dl \right)$$

$$\approx I_0 \exp \left[\frac{-0.17}{f^2 T^{3/2}} \langle N_e^2 L \rangle \right]$$

For a temperature $T = 10^4$ °K and an emission measure $\langle N_e^2 L \rangle = 5 \text{ cm}^{-6} \text{ pc}$, one would expect to observe the spectrum shown by the solid curve, and indeed it is a good fit to the observed points. Detailed interpretations of the spectrum on the basis of the observations made to date should be considered with caution, however, since the large uncertainties on most measurements embrace a rather wide range of spectral shapes.

CONCLUSIONS

Measurements of integrated cosmic noise intensities for a hemisphere centered near the North Galactic Pole have shown the spectrum to have a broad peak near 3 Mc/s at an intensity of about $2.7 \times 10^{-20} \text{ w/m}^2/\text{cps/sr}$. These results are not inconsistent with the concept of absorption by a uniform H II region in the solar neighborhood having an emission measure of 5 pc cm^{-6} . The shape of the spectrum below 5 Mc/s may give an indication of the degree of uniformity or the clumpiness of the ionized hydrogen, but the uncertainties in the present measurements do not make this possible. Observations with a directive antenna below 10 Mc/s will clarify this situation in considerable detail, and experiments of this nature are being planned (Alexander and Stone, 1964). In the meantime, there are at least three experimental areas which can contribute to solution of the problem. They are:

- (1) one or two intensity measurements below 1 Mc/s,
- (2) measurements with improved accuracy between 1 and 10 Mc/s,
- (3) measurements with some directivity between 10 and 20 Mc/s to facilitate extrapolation of the spectrum from high to low frequencies.

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REFERENCES

1. Alexander, J. K. and Stone, R. G., Ann.d'Astrophys. 27, 837 (1964).
2. Ellis, G. R. A., Nature 204, 171 (1964).
3. Hartz, T. R., Ann.d'Astrophys., 27, 823 (1964).
4. Huguenin, G. R., Lilley, A. E., McDonough, W. H., and Papagiannis, M. D., Harvard College Observatory Rpt. HSRP-107 (1963).
5. Walsh, D., Haddock, F. T., and Schulte, H. F., COSPAR, 6th Plenary Meeting, Warsaw (1963).